

EXECUTIVE SUMMARY

Introduction

Governor Martin O'Malley signed Executive Order 01.01.2010.16 ("EO") on July 23, 2010 directing the Maryland Department of Natural Resources' Power Plant Research Program ("PPRP") to prepare the Long-term Electricity Report for Maryland ("LTER").¹ The purpose of the LTER is to provide a comprehensive assessment of approaches to meet Maryland's long-term electricity needs as the State faces many challenges for providing a sustainable energy future through clean, reliable, and affordable power for all Marylanders. To address the issues set forth in the EO, PPRP assessed future electric energy and peak demand requirements for Maryland over the 20-year period from 2010 through 2030. Meeting those needs was assessed under an array of alternative future economic, legislative, and market conditions. Assessment of the alternatives is based on:

- Cost and cost stability;
- Reliability;
- Environmental impacts;
- Land use impacts;
- Consistency with the State's energy and environmental laws; and
- Consistency with federal energy and environmental laws.

To conduct the analysis, a LTER Reference Case ("RC") was developed along with alternative scenarios to allow estimation of the implications of different economic, regulatory, and infrastructure conditions over the course of the 20-year study period. The LTER Reference

¹ A copy of the Executive Order is included with this report as Appendix A.

Case is based on a set of assumptions and projections assessed as a plausible “business as usual” situation. The alternative scenarios include specific assumptions and projections different from those contained in the LTER Reference Case. These scenarios facilitate the isolation of the potential impacts of significant policy changes, external factors (such as natural gas prices and load growth) and infrastructure modifications that could affect costs, emissions, the scheduling of new power plant development, fuel use, the types of power plants added to the capacity portfolio, fuel diversity, and other results. In total, 33 alternative scenarios are defined and analyzed. These scenarios are briefly described in Table ES.1.

The outcomes of the LTER Reference Case, as well as those of the 33 alternative scenarios, are highly dependent upon the assumptions and projections used to develop the scenario. While these assumptions and projections represent plausible scenarios, the outcomes could change significantly if real-world experience differs from the projections. Additionally, the modeling scenarios represent a narrow evaluation focusing primarily on economic issues. There may be benefits that accrue to end-use customers (and Maryland residents at large) that are not fully captured by such a model. These benefits include, but are not limited to, emissions reductions, system reliability, increased diversity of fuel, overall economic development, and improvements in public health and welfare.

Table ES.1 LTER Scenarios

Category	Scenarios	Description
LTER Reference Case ("RC")	LTER Reference Case assumptions	See Table ES-2
Infrastructure Alternative Scenarios	Mt. Storm to Doubs Transmission Upgrade ("MSD")	RC assumptions with the MSD upgrade increasing transmission capacity between Western PJM and Maryland beginning in 2015.
	Mid-Atlantic Power Pathway ("MAPP") Transmission Line	RC assumptions with the MAPP line increasing transmission capacity between Maryland the Delaware/New Jersey region beginning in 2018.
	Calvert Cliffs 3 ("CC3")	RC assumptions with CC3 on-line in 2019 at a capacity of 1,600 MW.
	Calvert Cliffs 3 & National Carbon Legislation ("NCO2")	RC assumptions with CC3 and NCO2 starting in 2015 at \$16 per ton of CO and increasing to \$54 per ton by 2030.
	Mt. Storm to Doubs and MAPP Transmission Lines	RC assumptions with both MSD and MAPP added.
	Calvert Cliffs 3, National Carbon Legislation, Mt. Storm to Doubs, and MAPP	RC assumptions with the CC3, NCO2, MSD, and MAPP assumptions listed above.
National Carbon Legislation Alternative Scenarios	National Carbon Legislation	RC assumptions with NCO2 assumptions as noted above.
	National Carbon Legislation and Mt. Storm to Doubs	RC assumptions with NCO2 and MSD assumptions as noted above.
Natural Gas Price Alternative Scenarios	Lower Priced Natural Gas	Natural gas price assumption lowered so it reaches \$4.63 in 2030. Other RC assumptions unchanged.
	Lower Priced Natural Gas and Mt. Storm to Doubs	Lower natural gas price assumption and MSD added to the RC.
	Higher Priced Natural Gas	Natural gas price assumption increased so it reaches \$11.70 in 2030. Other RC assumptions unchanged.
	Higher Priced Natural Gas and Mt. Storm to Doubs	Higher natural gas price assumption and MSD added to the RC.
Load Growth Alternative Scenarios	Lower Load Growth	Load growth lowered by approximately 10 percent. Other RC assumptions unchanged.
	Lower Load Growth and Mt. Storm to Doubs	Lower load growth and MSD added to the RC.
	Lower Load Growth, Calvert Cliffs 3, National Carbon Legislation, Mt. Storm to Doubs, and MAPP	Lower load growth and CC3, NCO2, MSD, and MAPP added under the assumptions noted above.
	Higher Load Growth	Load growth raised by approximately 10 percent. Other RC assumptions unchanged.
	Higher Load Growth and Mt. Storm to Doubs	Higher load growth and MSD added to the model.
	Higher Load Growth, Calvert Cliffs 3, National Carbon Legislation, Mt. Storm to Doubs, and MAPP	Higher load growth and CC3, NCO2, MSD, and MAPP added under the assumptions noted above.

Category	Scenarios	Description
High Renewables Alternative Scenarios	High Renewables	Maryland RPS reaches 30 percent by 2030 and met with in-State renewable energy development.
	High Renewables and Mt. Storm to Doubs	30 percent RPS and MSD added to the RC.
	High Renewables, Calvert Cliffs 3, and National Carbon Legislation	30 percent RPS with CC3 and NCO2 assumptions as described above.
	High Renewables, Calvert Cliffs 3, National Carbon Legislation, Mt. Storm to Doubs, and MAPP	30 percent RPS with the CC3, NCO2, MSD, and MAPP added under the assumptions noted above.
Aggressive Energy Efficiency Alternative Scenarios	Aggressive Energy Efficiency	Maryland fully meets the EMPOWER Maryland ("EMP") goals by 2020. Other RC assumptions unchanged.
	Aggressive Energy Efficiency and Mt. Storm to Doubs	EMP goals met with the MSD line added to the model.
	Aggressive Energy Efficiency, Calvert Cliffs 3, and National Carbon Legislation	EMP goals met with CC3 and NCO2 added under the assumptions noted above.
	Aggressive Energy Efficiency, Calvert Cliffs 3, National Carbon Legislation, Mt. Storm to Doubs, and MAPP.	EMP goals met with CC3, NCO2, MSD, and MAPP added under the assumptions described above.
Climate Change Alternative Scenarios	Climate Change	PJM December 2010 Base Case Load Forecast adjusted for a 2.3°F increase by 2030. Other RC assumptions unchanged.
	Climate Change, Calvert Cliffs 3, National Carbon Legislation, Mt. Storm to Doubs, and MAPP	Adjusted load growth forecast with CC3, NCO2, MSD, and MAPP added under the assumptions described above.
Additional Scenarios	Coal Plant Life Extension and Mt. Storm to Doubs	Coal-fired power plant life extended and MSD added to the RC.
	PJM High Energy Efficiency and Low Load Growth	The lower load growth assumptions combined with aggressive energy efficiency policies in all PJM states.
	Proposed Environmental Protection Agency ("EPA") Regulations and Mt. Storm to Doubs	The new EPA regulations respecting mercury and cooling water added to the model and MSD added to the RC.
	Aggressive Energy Efficiency and High Renewables	A combination of the aggressive EE and high RPS assumptions in Maryland.
	Medium Renewables Scenario	An increase in the Maryland RPS requirement midway between the RC and the High Renewables scenario.

For each of the scenarios, including the LTER Reference Case, model simulations were run. The assumptions and projections required to be input into the model include:

- Energy consumption and peak demand;
- Power plant operating characteristics (operating costs, capacity, fuel, heat rate, capital costs, and emission rates for CO₂, SO₂, NO_x, and mercury) for all existing power plants and generic power plant types that the model may select for addition to the portfolio of power plants on a least-cost basis;
- Data related to the configuration and carrying capacity of the electric transmission system;
- Quantitative reliability requirements;
- Regulatory environment (state renewable energy portfolio standards, environmental restrictions on (or allowance prices for) specific pollutants);
- Fuel prices (natural gas, coal, oil, uranium);
- Power plant retrofit costs; and
- Certain other assumptions and projections.

A summary of the key assumptions and projections for the LTER Reference Case is presented in Table ES.2. The key assumptions and projections for the alternative scenarios are presented in Table ES.3.

Table ES.2
Summary of Key Assumptions and Projections for the LTER Reference Case

Assumption/Projection Issue	Description
Energy and peak demand forecast	PJM's December 2010 Base Case forecast for energy and peak demand was relied upon but modified to account for energy efficiency and conservation programs in Maryland (EmPOWER Maryland) and those in place in other PJM states and also modified for the projected impacts of plug-in electric vehicles on loads in Maryland and PJM.
Transmission infrastructure	The transmission infrastructure includes all PJM transmission lines, and transmission lines in other regions, in place in 2010 plus the Trans-Allegheny Interstate Line ("TrAIL"), which was energized in June 2011. (Note: alternative scenarios address the construction of the Mid-Atlantic Power Pathway (MAPP) and the upgrade of the Mt. Storm to Doubs transmission line.)
Natural gas prices	Natural gas prices are projected to increase from \$4.46/mmBtu in 2011 (2010\$) to \$8.01/mmBtu in 2030 (2010\$). (Note: alternative scenarios address higher and lower natural gas price projections.)
Coal prices	Coal prices (delivered) vary by transmission zone over the 20-year forecast period, but in general remain relatively flat.
Nuclear fuel prices	Nuclear fuel prices are projected to decline from \$0.75/mmBtu (2010\$) in 2011 to \$0.66/mmBtu (2010\$) in 2030.
Wind power capacity factors	On-shore and off-shore wind turbines are assumed to operate at a 30 percent capacity factor and a 40 percent capacity factor, respectively.
Solar capacity factor	Photovoltaic systems are assumed to operate at a 15 percent capacity factor.
Wind power construction costs	On-shore and off-shore wind projects are assumed to have an overnight construction cost in 2010 dollars of \$2,200 per kW and \$4,260 per kW, respectively.
Nuclear power plant construction costs	New nuclear generation facilities are assumed to have an overnight construction cost of \$5,870 per kW (2010\$).
Financial assumptions	The debt/equity ratio for new power plants is assumed to be 50 percent debt and 50 percent equity; the nominal cost of debt is assumed to be 7 percent; the nominal cost of equity is assumed to be 12 percent; the annual inflation rate is assumed to be 2.5 percent.
Renewable energy portfolio standards ("RPSs")	It is assumed that Maryland will meet its Tier 1 and Tier 2 RPS requirements through the retirement of Renewable Energy Certificates ("RECs"). The Maryland solar requirement is assumed to be met with solar RECs through 2018; for years following 2018, a portion of the solar RPS requirement would be met through Alternative Compliance Payments; by 2030, approximately 50 percent of the Maryland solar energy requirement is assumed to be met through Alternative Compliance Payments.
Environmental Regulations	EPA's existing regulations (the Clean Air Transport Rule, the Greenhouse Gas Tailoring Rule, and New Source Performance Standards) integrated into the model.
Energy Efficiency and Conservation Programs	EmPOWER Maryland goals for demand reductions are assumed to be fully met. The EmPOWER Maryland goals for energy reductions are assumed to be met at the 60% level. Energy efficiency and conservation programs in other states are assumed to meet their goals in rough proportion to the assumptions relied on for Maryland, but with more ambitious programs achieving a smaller percentage of their energy goals and less ambitious programs achieving a larger percentage.

Table ES.3
Summary of Key Assumptions and Projections for the LTER Alternative Scenarios

Assumption/Projection Issue	Description
Calvert Cliffs Nuclear Unit 3	For those scenarios that include construction of Calvert Cliffs 3, the plant capacity is assumed to be 1,600 MW; construction cost is assumed to be \$10 billion; and the in-service date is assumed to be 2019.
MAPP Transmission Line	The MAPP transmission line is assumed to come on-line in 2018 with a transfer capability of 2,500 MW between PJM Southwest and PJM Mideast, and a transfer capability of 1,250 MW between PJM Southwest and PJM South.
Mt. Storm to Doubs Transmission Line Upgrade	The Mt. Storm to Doubs transmission line upgrade is assumed to be in-service beginning in 2015 with a transfer capability of 1,700 MW between the Allegheny Power System region and PJM Southwest.
National Carbon Legislation	Assumed to become effective in 2015 and implemented as a cost on carbon emissions of \$16 per ton (2010 dollars) in 2015, increasing by \$1 per ton annually through 2023, then increasing at an average of \$4.50 per ton per year through 2030. A federal RPS is included with the carbon legislation and is set at 12 percent by 2020. States with more aggressive RPSs meet the higher standard.
High and Low Natural Gas Prices	The low gas price assumption is gas prices starting at \$3.56 per mmBtu in 2011 rising to \$4.63 by 2030. The high gas assumption is gas prices starting at \$5.50 per mmBtu in 2011 and increasing to \$11.70 by 2030. All prices are in 2010 dollars.
High and Low Loads	Low loads increase at a growth rate 0.5 percentage points below the LTER Reference Case growth rate. High loads increase at a growth rate 0.5 percentage points higher than the LTER Reference Case growth rate.
High Renewables	The Maryland RPS is increased from a 20 percent renewable requirement by 2022 to a 30 percent requirement by 2030. All RPS compliance, including the solar carve-out, is met through retirement of Renewable Energy Certificates.
Aggressive Energy Efficiency	Maryland implements more aggressive energy efficiency/conservation programs such that 100 percent of the EmPOWER Maryland energy reduction goal is achieved by 2020 and demand reductions equal to 150 percent of the EmPOWER Maryland goal are achieved by 2030.
Climate Change	Average ambient temperatures increase by 2.3 degrees Fahrenheit by 2030 compared to long-term normal temperatures, with temperature increases between 2010 and 2030 linearly interpolated.

Key Results

The results of the model runs include, but are not limited to, information on power plant additions and retirements; fuel consumption by fuel type; emissions from Maryland generation and, alternatively, by consumption; energy and capacity prices; and net imports of energy by

transmission zone. The modeling was conducted using the Ventyx Integrated Power Model (“IPM”). The IPM, developed by Abb/Ventyx, is a set of models designed to reflect the market factors affecting power prices, emissions, generation, power plant development (and retirements), fuel choice, and other power market characteristics. The IPM is a zonal model, which separates the PJM Region (and other regions) into distinct zones based on transmission paths and electric utility territories. In the IPM, different portions of Maryland are in three different zones – PJM Mid-Atlantic Southwest, PJM Mid-Atlantic East, and PJM Allegheny Power Systems (“APS”).² Some of the modeling results, therefore, are at the zonal level.

LTER REFERENCE CASE RESULTS

- No new generating capacity is needed in PJM to meet reliability requirements before 2018. Between 2010 and 2030, PJM adds approximately 30,000 MW of new natural gas-fired capacity.
- Based on least-cost criteria, all new generating capacity projected to be constructed to satisfy reliability requirements will be fueled by natural gas. Renewable generating capacity is also added during the 20-year study period to meet RPS requirements in Maryland and other states.
- Approximately 16,250 MW of renewable generating capacity is added to PJM between 2010 and 2030.
- Emissions of NO_x, SO₂, and mercury from Maryland power plants subject to Maryland’s Healthy Air Act (“HAA”) remain below the HAA caps for those pollutants throughout the 20-year study period.

² PJM Mid-Atlantic Southwest contains Baltimore Gas & Electric, Pepco (both Maryland and Washington D.C. service territories) and the Southern Maryland Electric Cooperative. PJM Mid-Atlantic East contains all of New Jersey, Delmarva Power (both Maryland and Delaware territories) and PECO Energy Company. PJM APS covers the entire Allegheny Power System company footprint.

- Emissions of CO₂ exceed Maryland's budget under the Regional Greenhouse Gas Initiative ("RGGI") beginning in 2020, which will require Maryland generation facilities to purchase RGGI emission allowances from other RGGI states and/or purchase offsets in order for the State to comply with its RGGI commitments.
- Real energy prices are projected to increase by between 5 and 6 percent per year through 2020, then remain relatively flat for the final 10 years of the study period. The increase in prices during the first ten years of the period largely reflects increases in fuel prices and increasing reliance on less efficient generating units to meet consumption requirements. During the second 10-year period, the impact of increases in fuel prices is off-set by the construction of new, more efficient power plants.
- Capacity prices, which can increase or decrease significantly from year to year, generally increase over the 2010 through 2030 period and begin to converge at prices approximating the cost of new entry (about \$250 per MW-day) towards the end of the study period.

ALTERNATIVE SCENARIO RESULTS

Capacity Additions

- Under assumptions of high load growth over the study period, PJM adds between 52,000 and 58,000 MW of new gas-fired generating capacity compared to 30,000 MW in the LTER Reference Case.
- Under assumptions of low load growth over the study period, PJM adds between 8,000 and 15,000 MW of new gas-fired capacity compared to 30,000 MW in the LTER Reference Case.
- The implementation of more aggressive energy efficiency and conservation programs in Maryland results in a reduction in new gas-fired generating capacity in PJM of about 2,000 MW relative to the LTER Reference Case.

- Relative to the LTER Reference Case, the adoption of national carbon legislation results in approximately 7,000 MW of additional PJM-wide natural gas-fired power plants over the 20-year study period, which reflects increased retirements of coal-fired plants and reduced coal-fired generation from retrofitted coal plants.
- Construction of new transmission lines in PJM (the MAPP line and the Mt. Storm to Doubs transmission line upgrade) are shown to have little or no effect on PJM-wide power plant additions over the study period.

Energy Prices

- Wholesale energy prices under most alternative scenarios are generally consistent with the LTER Reference Case energy prices with two exceptions – natural gas price scenarios and the scenarios that consider national carbon legislation. Under the other alternative scenarios, wholesale energy prices vary only marginally from the LTER Reference Case energy prices.
- Under assumptions of high natural gas prices, all-hours wholesale energy prices are approximately \$21 to \$25 per MWh (in 2010 dollars) higher than the LTER Reference Case energy prices by 2030.
- Under assumptions of low natural gas prices, all-hours wholesale energy prices are approximately \$22 per MWh (in 2010 dollars) lower than the LTER Reference Case energy prices by 2030.
- Under assumptions of national carbon legislation, all-hours wholesale energy prices are approximately \$21 per MWh (in 2010 dollars) higher than the LTER Reference Case energy prices by 2030.

Maryland Emissions based on Maryland Generation

- Under all of the scenarios considered, in-State emissions of SO₂, NO_x, and mercury are below the caps imposed by Maryland's Healthy Air Act.

- In-State CO₂ emissions vary by scenario. In general, CO₂ emissions exceed Maryland's budget under the Regional Greenhouse Gas Initiative during the course of the study period.
- Development of the Mt. Storm to Doubs transmission line upgrade reduces the amount of CO₂ emissions in Maryland since construction of the line facilitates greater levels of imported energy from more western portions of PJM. (Note: CO₂ emissions in PJM are not reduced as a result of this line, but CO₂ emissions from Maryland power plants are.)
- Construction of the Calvert Cliffs 3 nuclear power plant reduces in-State CO₂ emissions by over 10 percent (approximately 4 million tons per year relative to the LTER Reference Case).
- The introduction of national carbon legislation reduces CO₂ emissions in Maryland by approximately 8 percent (3 million tons per year) by 2030.
- Under the high load growth assumption, emissions of CO₂ in Maryland increase relative to the LTER Reference Case by approximately 10 percent by 2030. Under the low load growth assumption, there is a significant reduction in CO₂ emissions in Maryland relative to the LTER Reference Case beginning in the early to mid-2020s. By 2030, however, there is only a slight difference between the LTER Reference Case and the low load scenarios. (Under the low load scenario, fewer new, more efficient plants are being added relative to the LTER Reference Case, which serves to erode a large portion of the reduced CO₂ reductions that would be achieved under conditions of lower loads with other factors held constant).
- The high renewables scenario, which is based on the assumption of a 30 percent RPS by 2030 in Maryland, reduces Maryland CO₂ emissions by approximately 3 percent by 2030 relative to the LTER Reference Case.
- The high energy efficiency/conservation scenario, which is based on adoption of a more aggressive energy efficiency/conservation program in Maryland, results in reduced CO₂ emissions of approximately 6 percent by 2030 relative to the LTER Reference Case.

Maryland Emissions Based on Maryland Consumption

- Emissions of CO₂ and SO₂ are highest (relative to the LTER Reference Case) under the high gas price scenarios since there are fewer retirements of coal fired facilities and coal generation runs more intensively. The lowest levels of CO₂ emissions are associated with the high renewables scenarios, the low gas price scenarios, and the scenarios that include construction of Calvert Cliffs 3 combined with national carbon legislation. The lowest levels of SO₂ emissions are associated with the high renewables scenarios and the scenarios that include national carbon legislation.
- Emissions of mercury are highest under the low load scenarios, since fewer new, more efficient plants are being built and there is a heavier reliance on coal-fired generation. In general, however, there is not a large degree of variation in mercury emissions among the scenarios.
- Emissions of NO_x are lowest under the high renewables scenarios and the scenarios that include national carbon legislation. The highest levels of NO_x emissions are associated with the scenarios that assume relatively slow growth in loads and those that assume high natural gas prices (relative to the LTER Reference Case).

Fuel Diversity

- For all scenarios, fuel supply diversity increases over the course of the 20-year study period as the share of coal-fired generation declines and the proportion of generation relying on natural gas increases.
- The greatest increases in fuel diversity are related to the scenarios that include construction of Calvert Cliffs 3, high load growth, and high renewables development.
- The smallest increases in fuel diversity are associated with those scenarios that entail slower growth in load, such as the low load growth scenarios and the high energy efficiency scenarios.

Capacity Prices

- In general, capacity prices increase when capacity becomes tight in a zone, and decline following the introduction of a new power plant.
- The general trend is for capacity prices to be relatively low in the early years of the study period, then to increase as the need for new generating capacity increases and plants begin to be built within the model. There is a general tendency for the capacity prices among zones to converge towards the end of the study period, and gravitate towards values that approximate the cost of new power plant entry.

Land Use

- Land use requirements on a per-MW-of-installed-capacity basis are significantly higher for on-shore wind and solar than for nuclear and natural gas-fired capacity.
- Land use requirements for on-shore wind capacity on a per-MW basis are approximately ten times higher than for solar capacity.
- Maryland land-use requirements for all scenarios except the High Renewables scenarios are between 15,000 and 20,000 acres for all new generating capacity over the 20-year study period. For all of the scenarios, the majority of land use requirements are associated with new renewable energy projects.
- For the High Renewables scenarios, Maryland land use requirements for new generation exceed 100,000 acres over the 20-year study period. Almost all of that requirement is related to the development of on-shore wind generation.³

³ For the High Renewables scenarios, it is assumed that all additional renewable energy projects required to meet a more aggressive Maryland Renewable Energy Portfolio Standard would be sited in Maryland. On-shore wind eligible to meet Maryland's RPS, however, may be located outside Maryland. To the extent that the higher RPS requirements assumed under the High Renewables scenarios would be sited outside Maryland, the Maryland land use requirements estimated for these scenarios would be correspondingly lower.

Renewable Energy Certificate Prices

- Under the LTER Reference Case and the High Renewables scenarios, Tier 1 RECs prices are estimated to range between \$2 per REC to \$28 per REC (in 2010 dollars). RECs prices increase through 2014, then stabilize within the range of \$24 per REC to \$26 per REC between 2015 and 2023. After 2023, RECs prices decline in real terms to a level of \$12 per REC by 2030.
- For the scenarios that entail significantly higher energy prices than projected for the LTER Reference Case (for example, the cases that include national carbon legislation and high natural gas prices), the projected RECs prices (2010 dollars) are lower than in the LTER Reference Case and drops to zero towards the end of the study period. The reason for this result is that the RECs prices are calculated as the residual revenue required by a new renewable energy project to cover all costs of ownership and operation, and the federal Production Tax Credit incentive. Higher market prices for energy, therefore, result in a smaller residual revenue requirement that would need to be recovered through RECs prices.
- The low natural gas price scenarios result in the highest projected RECs prices due to the low energy prices projected for these scenarios. Nominal RECs prices, if unconstrained, would exceed the \$40-per-REC Alternative Compliance Payment (“ACP”) contained in the RPS legislation beginning in 2019 and extending through the end of the 20-year study period. Since the ACP acts as a cap on RECs prices, nominal RECs prices were assumed to reach a maximum of \$38 per REC, with the \$2-per-REC difference between the \$40 ACP and \$38 assumed maximum value representing the transaction costs. In real terms, RECs prices under the low natural gas price scenarios reach \$33 per REC in 2013, and decline to \$23 per REC in 2030.

SUMMARY

Table ES.4 ranks the production costs, generator revenues, emissions, fuel diversity, and generic natural gas capacity builds across the scenarios. The first column of the table ranks the

total production costs over the 20-year study period (in 2010 dollars) associated with each scenario. Total production costs are calculated as the sum of fuel, fixed, and variable costs that generators in PJM incur to produce electricity. The fixed and variable costs include operations and maintenance (“O&M”) expenses as well as emissions costs. As shown in the total production cost column of Table ES.4, the scenarios that include implementation of national carbon legislation involve the highest total production costs.

The second column of Table ES.4 ranks the wholesale energy market revenues that generators earned throughout the study period (in 2010 dollars). Wholesale energy market revenues are highest in the scenarios that include national carbon legislation or high natural gas prices.

The third column of Table ES.4 ranks capacity market revenues earned by PJM generators over the study period (in 2010 dollars) and shows that capacity market revenues are typically highest under assumptions of high load, low natural gas, and aggressive energy efficiency and conservation.

Table ES.4 also ranks the total NO_x, SO₂, and CO₂ emissions from PJM generation units in each scenario. The ranking of the emissions across the three pollutants are generally stable, and scenarios with relatively high CO₂ emissions typically also have high NO_x and SO₂ emissions. It warrants mention that the total CO₂ emissions across the scenarios vary within a nine percentage point range, and the total NO_x and SO₂ emissions vary within a six percentage point range. The seventh column in Table ES.4 ranks the fuel diversity indices across scenarios.

The fuel diversity index is a measure of the mix of fuels used to generate electricity in PJM. A higher fuel diversity index indicates greater fuel diversity.

The last column of Table ES.4 ranks the total generic natural gas capacity (in MW) that was added by the model in PJM to satisfy load and reliability requirements. The scenarios that include national carbon legislation induce coal power plants to retrofit or retire and as such, these scenarios, along with the high load scenarios, involve higher levels of generic natural gas capacity additions.

Table ES.4
PJM-Wide Summary Statistics by Scenario

	Total Production Costs	Wholesale Energy Revenues	Capacity Revenues	Total NO _x Emissions	Total SO ₂ Emissions	Total CO ₂ Emissions	2030 Fuel Diversity Index*	Total Gas Capacity Built
LTER Reference Case	●	●	●	●	●	●	●	●
MSD	●	○	●	●	●	●	●	●
MAPP	●	●	●	●	●	●	●	●
CC3	○	○	○	●	●	●	●	○
MSD + MAPP	●	●	●	●	●	●	●	●
CC3 + NCO2	●	●	●	●	○	○	●	●
CC3/NCO2/MSD/MAPP	●	●	○	○	●	○	●	●
NCO2	●	●	●	●	●	●	●	●
NCO2 + MSD	●	●	●	●	●	○	●	●
High Gas	●	●	○	●	●	●	●	●
High Gas + MSD	●	●	○	●	●	●	●	●
Low Gas	○	○	●	●	○	●	●	○
Low Gas + MSD	○	○	●	●	○	●	●	●
High Load	●	●	●	●	●	●	●	●
High Load + MSD	●	●	●	●	●	●	●	●
High Load + CC3/NCO2/MSD/MAPP	●	●	●	○	●	○	●	●
Low Load	○	○	○	●	●	●	○	○
Low Load + MSD	●	○	○	●	●	●	○	○
Low Load + CC3/NCO2/MSD/MAPP	●	●	○	○	○	○	●	○
High Renew	○	○	●	○	○	●	●	○
High Renew + MSD	○	●	●	○	○	●	●	○
High Renew + CC3/NCO2	●	●	●	○	○	○	●	●
High Renew + CC3/NCO2/MSD/MAPP	●	●	○	○	○	○	●	●
EE	○	○	○	●	●	●	●	○
EE + MSD	○	○	●	●	●	●	●	○
EE + CC3/NCO2	●	●	●	○	○	○	●	●
EE + CC3/NCO2/MSD/MAPP	●	●	●	○	●	○	●	●
Climate Change	●	●	●	●	●	●	●	●
Climate Chg + CC3/NCO2/MSD/MAPP	●	●	●	●	●	●	●	●
● = top third	● = middle third	○ = bottom third						
*Fuel diversity indices are ranked as follows: ● = < 0.88 ● = ≥ 0.88 and ≤ 0.915 ○ = > 0.915								